Site and Reach Assessment
Puyallup River
at SR 162 Bridge 162/006

Work Order XL2760

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Summary and Recommendations

This report analyzes hydrologic and geomorphic issues that should be considered in the replacement of Bridge 162/006 over the Puyallup River. The report assesses watershed conditions, river hydrology, flood elevations and boundaries, local floodplain regulations, channel migration, sediment transport, scour, riparian conditions, and fish habitat.

Based on the results of this reach assessment, the following issues were considered in developing the bridge design:

Compliance with Pierce County's Flood Hazard/Critical Area Ordinance requirements. The new bridge was designed to minimize new floodplain fill and constriction of flood flows. Northwest Hydraulic Consultants (2014) analyzed the hydraulic characteristics of the river near the bridge for the 100-year flood flow, and found the proposed bridge would not cause an upstream water surface rise or decrease the flow conveyance for the 100-year event. The proposed design provides adequate freeboard between the lowest structural member and the 100-year base flood elevation.

Minimizing floodplain constriction and channel migration risks: The proposed bridge will be constructed adjacent to the existing alignment to minimize impacts to floodplains and riparian areas. This location is at a pinch point where the 100-year floodplain is narrowest (Figure 1). This is also a location where historical channel migration has been limited to a single channel that is confined between high banks, levees, and terraces (Figure 12), thus minimizing risks of channel migration to bridge supports. There is little potential for major channel changes or avulsion in this channel segment.

Channel migration risks and flood constriction will be further reduced by provide a wider bridge opening (approximately 270 feet proposed vs. 210 feet existing). This bridge length will also improve floodplain connectivity by spanning a low floodplain bench on the left bank that has been configured to offset impacts of pier blockage (Figure 2).

Maintaining existing tie-ins with levees. Road embankments should tie into the crests of adjacent levees to maintain the existing level of flood protection. Stormwater drainage systems should not create new flow paths across levee alignments. A levee on the right bank ties into the upstream side of the Burlington Northern/pedestrian trail embankment. A levee on the left bank ties into the downstream side of the SR 162 embankment.

Minimizing scour risks and impacts of piers on channel habitat: The proposed design avoids placing piers in the active channel to reduce the risk of scour and avoid impacts to ESA-listed fish. Piers foundations within Pierce County's Channel Migration Hazard zone will be designed to anticipate potential channel scour.

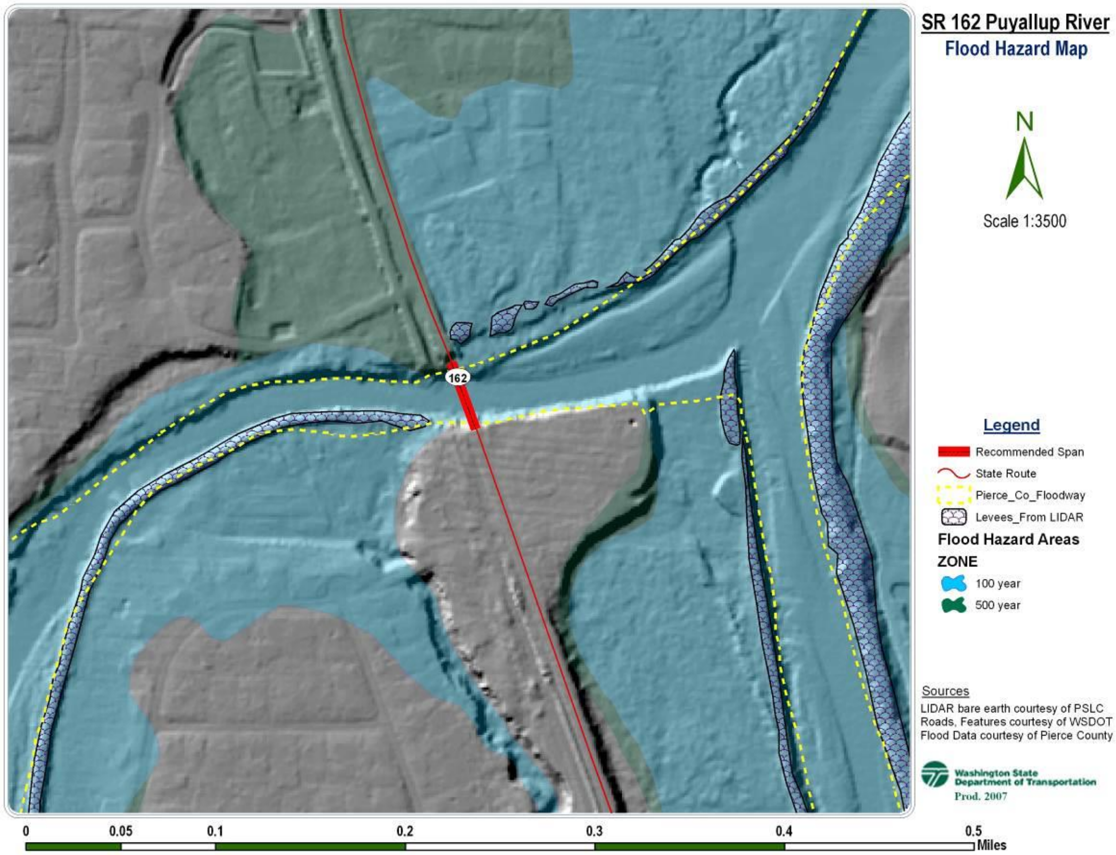

Figure 1. Flood Hazard Boundaries

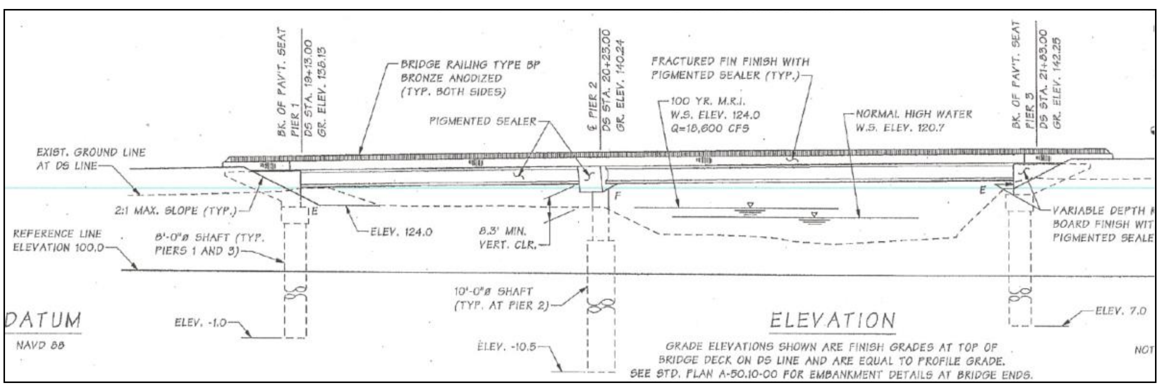

Figure 2. Proposed Bridge Cross Section (view facing downstream)

Introduction

Bridge 162/006 is located at SR 162 Milepost (MP) 6.81, and crosses the Puyallup River just upstream of the Carbon River confluence near Orting (Figure 3). The bridge is functionally obsolete and is slated for replacement. This report identifies hydrologic and geomorphic factors that should be considered in the design of the new bridge. The site assessment focuses on river conditions in the immediate vicinity of the bridge, while the reach assessment looks at larger-scale processes that could affect the stability of the river system.

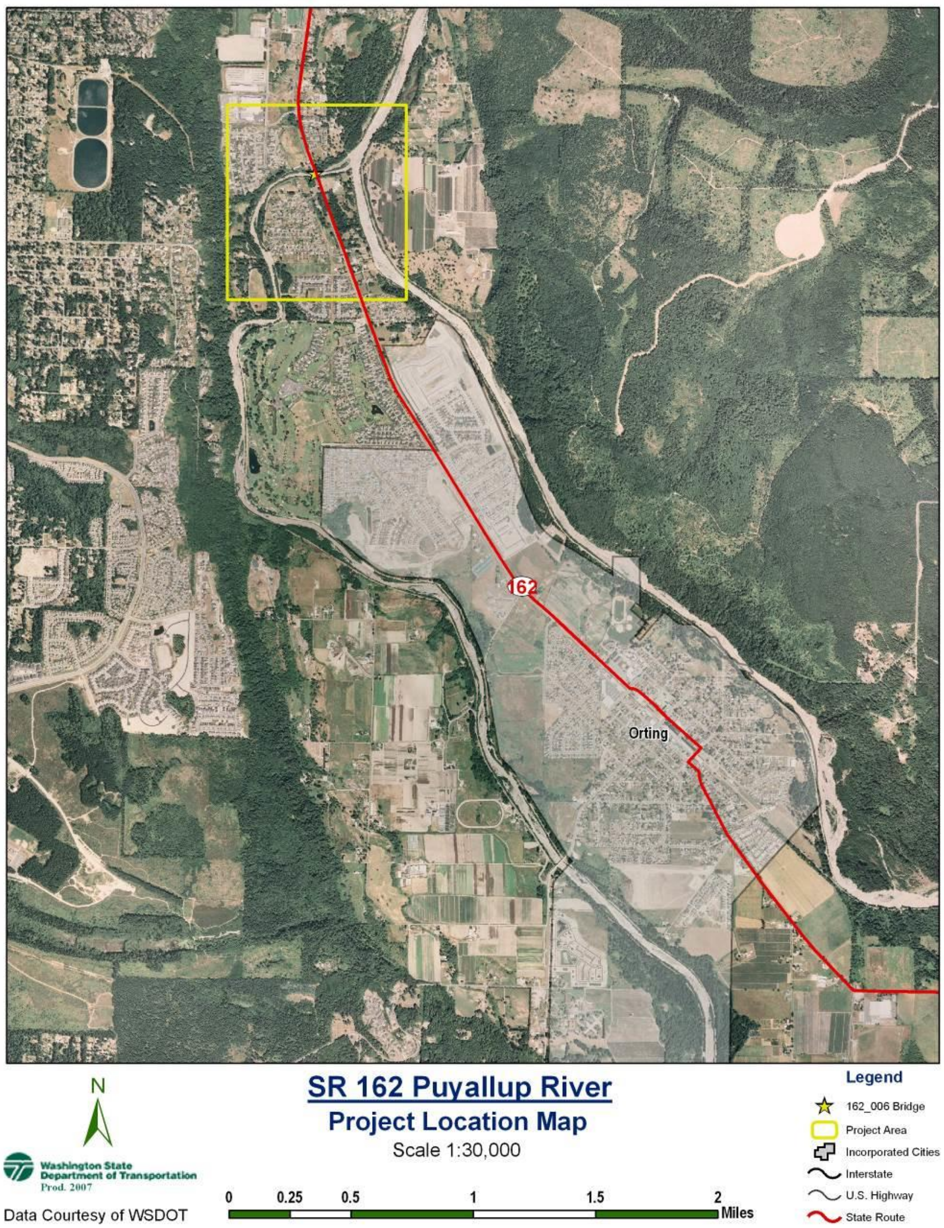

Figure 3. Project Location Map.

Site Assessment

Existing Bridge Design

Bridge 162/006 crosses the Puyallup at River Mile 17.71, about 0.2 miles upstream of the Carbon River Confluence (Northwest Hydraulics Consultants, 2006). The abandoned Burlington Northern Santa Fe railroad line crosses the river just upstream at RM 17.72, and has been converted to a pedestrian path.

Bridge 162/006 was built in 1934 as a reinforced concrete truss structure that spans the Puyallup River (Figure 4) (WSDOT, 2007). It is supported on each bank by piers on spread footings. The bridge consists of a 170-foot main span with 20-foot approaches on each bank. Piers 2 and 3 support the main span, and are placed at the edge of the active channel on each bank.

Figure 4. Photo of Bridge 162/006 from Downstream

Channel Geometry near the Bridge

Figure 5 shows cross sections of the river channel upstream and downstream of the bridge derived from LIDAR. The channel is relatively uniform just upstream of the Burlington Northern bridge, with only a narrow band of sand exposed at the toe of each bank. The channel geometry becomes more complex downstream as sediment deposits develop along the left bank.

The right bank slopes steeply up from the channel bed at about 1:1 (Horizontal: Vertical). The top of the right bank upstream of the bridges ties into an un-maintained levee with a crest that is less than 4-feet above the adjacent floodplain. This levee fades into riparian forest and blackberry thickets before tying into the upstream side of the Burlington

Northern/pedestrian path embankment. At and downstream of the SR 162 bridge the right bank ties into a flat terrace of mudflow deposits that sits well above adjacent floodplains.

The left bank is generally lower than the right bank, and ties into adjacent floodplains. The SR 162 and Burlington Northern bridge approaches are both elevated above the left bank floodplain. The Burlington Northern bridge approach is higher than SR 162. Upstream of the bridges the left bank is relatively steep (about 1:1), but becomes shallower and more complex downstream where the river has deposited berms of coarse sediment.

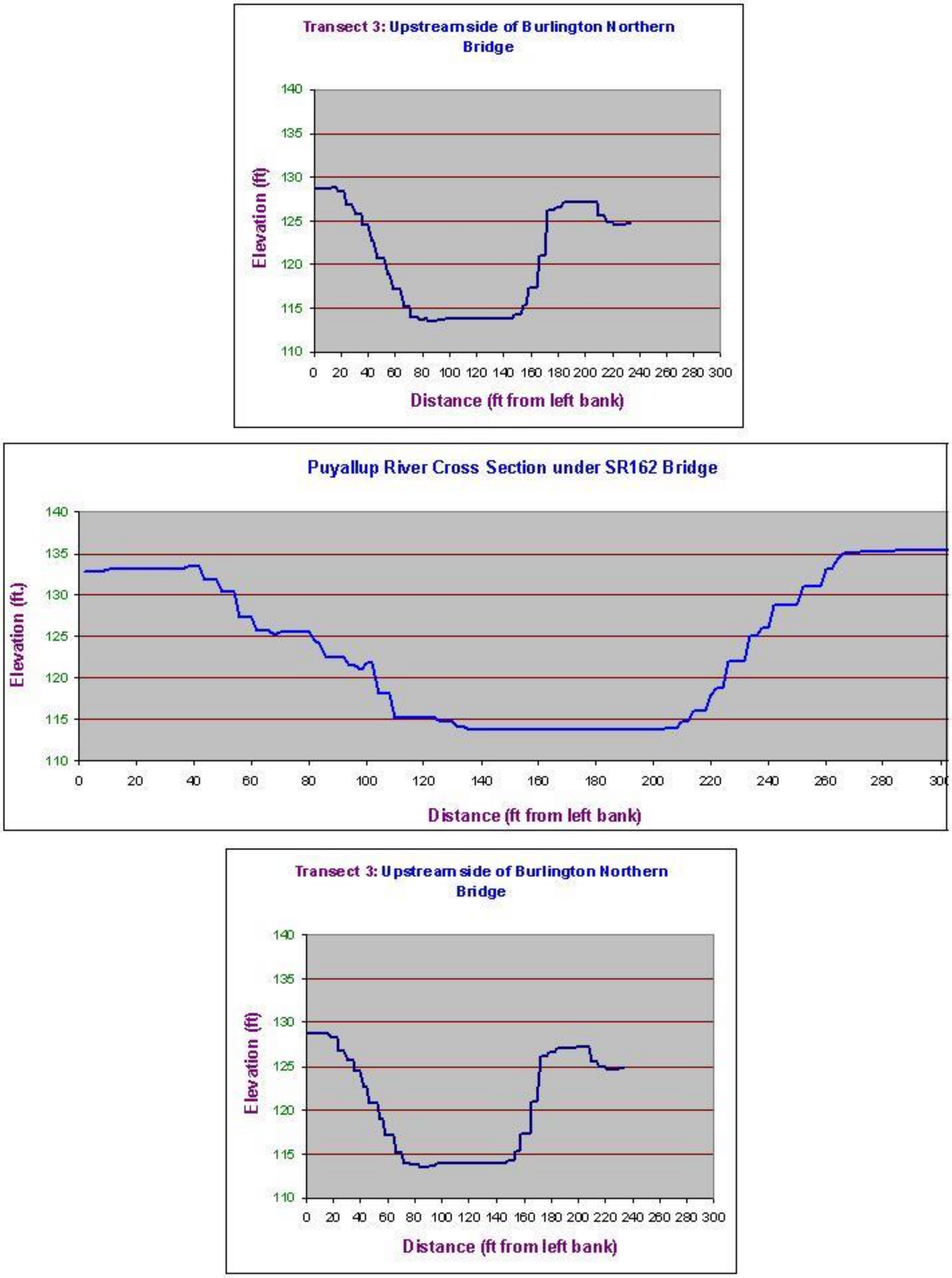

Figure 5. River Cross-Sections near Bridge 162/006 from LIDAR

Scour and Sediment Deposition

WSDOT Bridge Inspection Reports from 1995 through 2005 noted that the west abutment cap was undermined and H-piles were exposed up to 16 inches (WSDOT, 2007). The original 1934 bridge plans indicate scour concentrated next to the right bank abutment pier (Pier 3). Large chunks of 3- to 6-foot concrete rubble cover the base of Pier 3 to protect against scour (Figure 6). On the left bank Pier 2 is buried in a sandy slope, and shows no sign of scour.

Figure 6. Photo of Armor around the Base of Pier 3

The channel thalweg curves around a right bank sand bar on the inside of a bend about 500 feet upstream of the bridge. As it approaches the bridges the thalweg then winds back against the right bank, concentrating flow energy against the right bank piers. At bridge 162/006 the thalweg drops into a scour hole next to Pier 3, and remains concentrated against the right bank down to the Carbon River confluence. This pattern of flow has remained relatively constant in historical aerial photos.

Extensive sediment deposition begins downstream of the bridge, and is probably related to the backwater effects of sediment deposited at the Carbon River confluence (Figures 7 and 8). A sand bar begins at the base of the left bank under the bridge, and becomes steadily wider and coarser downstream. About 200 feet below the bridge this bar consists of gravel and cobble embedded in fine sand, and slopes upward onto a gravel and cobble berm with a high flow channel along the back edge (at the toe of the riverbank). The width of the bar exposed in the late summer increases from about 30-feet just below Bridge 162/006 to over 80-feet about 200-feet downstream.

Figure 9 shows the bed profile of the river used in the updated flood study for the Puyallup River (Northwest Hydraulics Consultants, 2006). The river approaches the bridge at a relatively gentle gradient of 0.1 percent. This profile shows a 7-foot drop in the riverbed at the SR 162 bridge, indicating significant scour beneath the bridge. Coarse sediment deposits at the Carbon River confluence create a virtually flat riverbed profile downstream of the bridge.

Figure 7. Photo of Sediment Deposits Downstream from Bridge 162/006

Figure 8. 2006 Aerial Photo of the SR 162 Bridge Site

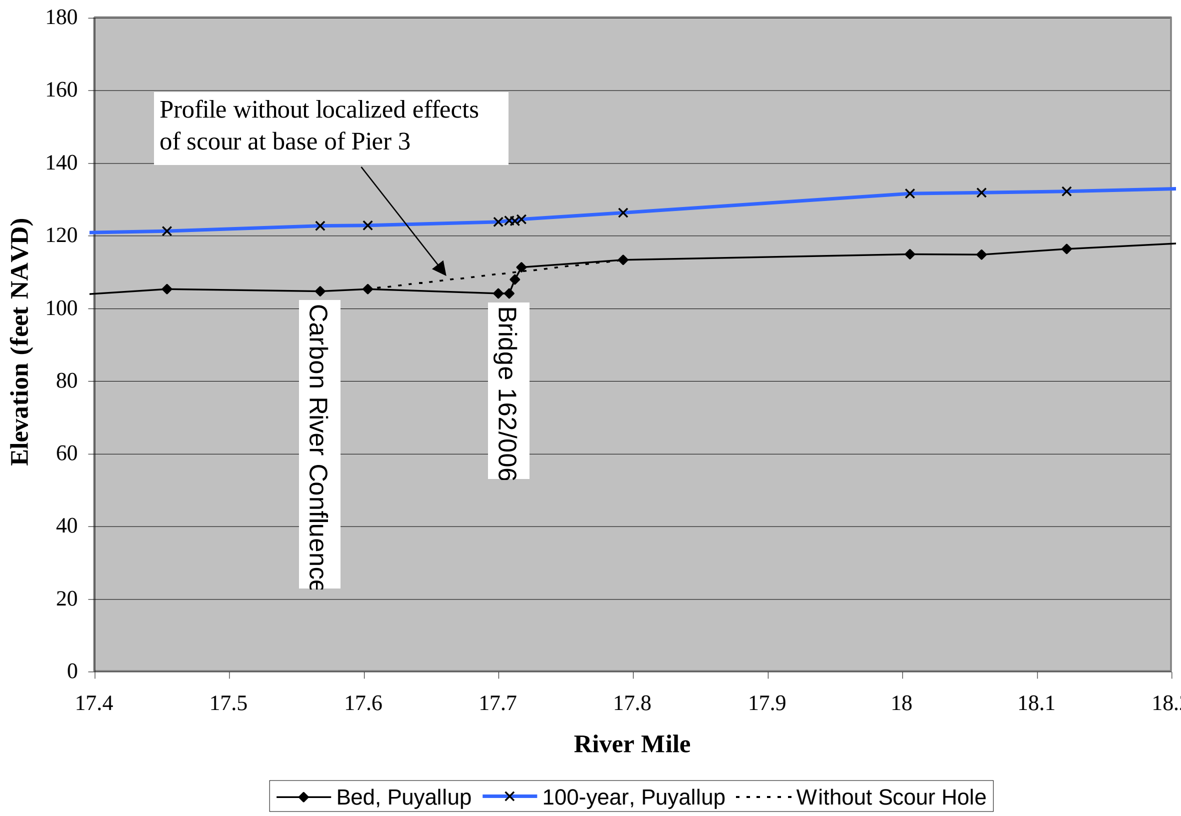

Figure 9. River Bed Profiles near Bridge 162/006

We did not observe this distinctly stepped river profile at the bridge during our September 2007 site visit. The drop in the flood study profile is probably caused by a localized scour hole at the base of Pier 3. Cross-sections below the bridge are widely-spaced, and therefore do not show the more gradual transition that the overall bed profile follows as it passes beneath the bridge. The dashed line in Figure 9 shows our hypothesized general profile, neglecting the localized effects of the scour hole at Pier 3.

Riparian Habitat and Large Woody Debris

The left bank downstream of the bridge contains the highest quality riparian habitat, with a 130-foot band of relatively mature deciduous trees mixed with a few large Douglas firs (Figure 8). Big leaf maple (50- to 60-foot height), black cottonwood (up to 100-foot height), and red alder dominate this riparian area. A levee runs through the upslope edge of this riparian area, but is covered by mature trees and does not appear to be maintained. A large clump of Japanese knotweed is invading the margin of the riparian zone along the SR 162 embankment. Upstream of the bridge the left bank riparian area is narrower (50-60 feet wide) and is dominated by red alder (less than 30-foot height) interspersed with big leaf maple (50- to 60-foot height).

The riparian forest is less healthy on the right bank. Riparian trees are confined to the steep bank slope downstream of the bridge, and consist primarily of immature red alder and big leaf maple. At the top of the bank the riparian area transitions onto manicured lawn. Vegetation is less confined by development upstream of the bridge, but is dominated by immature deciduous trees and invasive Himalayan blackberry. Trees have been cleared from a levee that parallels the upstream right bank.

We observed no Large Woody Debris in the river channel near the bridge, aside from a few alder trunks (less than 1-foot diameter) wedged among remnant pilings.

Aquatic Habitat

A variety of salmonid species use the Puyallup River, but habitat for spawning and juvenile rearing is limited near the bridge. Gravel deposits that would otherwise be suitable for spawning are often covered by or embedded in fine sands and glacial silts. Channel confinement by levees causes scour of redds and diminished spawning success (Washington State Conservation Commission, 1999). Confinement has also created a simplified river channel with no off-channel rearing habitat. It is likely that most fish species use this stretch of river primarily for migration to more suitable spawning and rearing habitats.

Reach Assessment

The reach assessment focuses on river processes upstream and downstream of the bridge that could affect the long-term stability of the channel. The project reach for this study begins at the confluence with the Carbon River at River Mile 17.5, and extends upstream to the Calistoga bridge near River Mile 21.5 in Orting.

Watershed Conditions and Land Cover

The Puyallup River is fed by meltwater from the North Mowich, Edmunds, South Mowich, Puyallup and Tahoma glaciers on the west flank of Mt. Rainier. The river drains 185 square miles at the project site, and is located in Water Resources Inventory Area 10. In the project reach it occupies a broad floodplain bounded by steep bluffs. Elevations range from 100 feet at the project site to 14,411 feet at the summit of Mt. Rainier.

Logging of old growth forest began in the 1850's, and by the early 1900's most of the valley floor was cleared for agriculture. Until recently intense urban development was concentrated in the town of Orting, and the majority of the valley floor was devoted to agricultural uses. Since the 1990's several large residential subdivisions have been constructed outside of Orting, converting most fields near the SR 162 bridge to suburban residential uses.

Geology and Soils

The SR 162 bridge lies within a broad alluvial valley that was originally carved by meltwater from continental glaciers. Steep bluffs of mixed glacial drift, till, and outwash form the valley walls. Receding glaciers left behind terraces of glacial outwash that mark the transition between the bluffs and the valley floor (Figure 10).

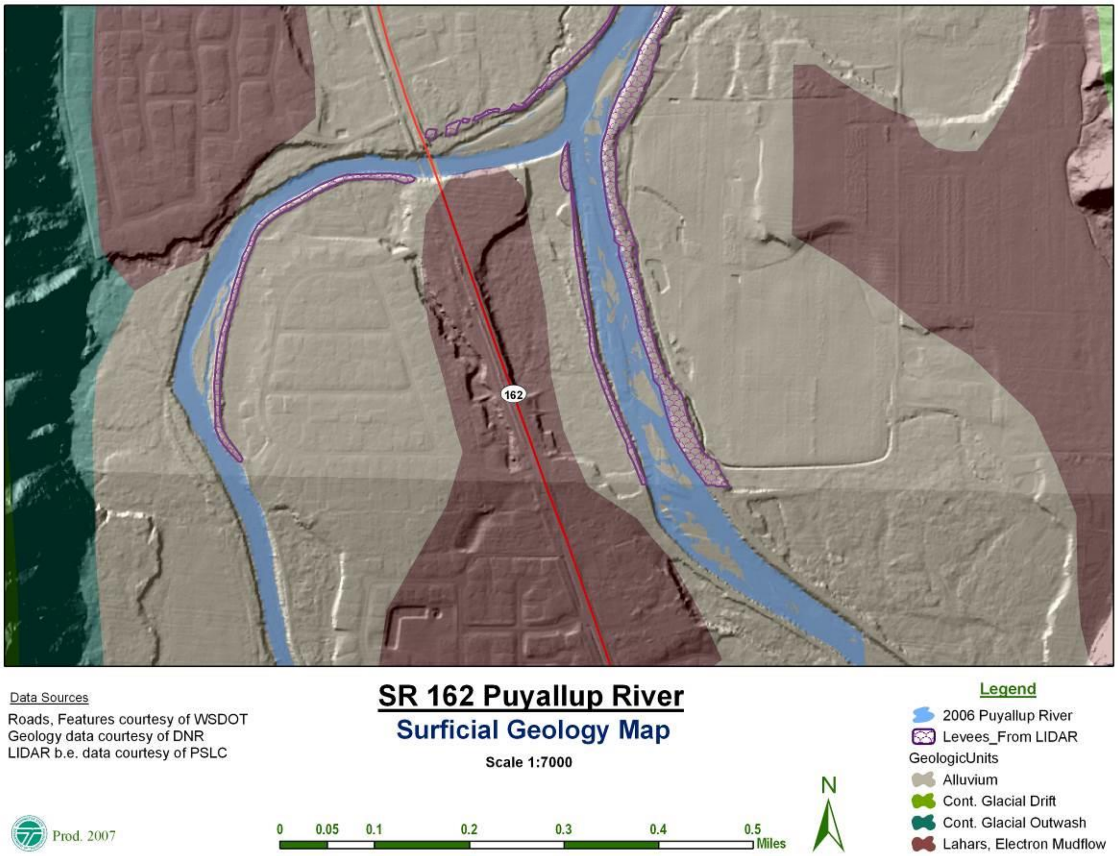

Figure 10. Surficial Geology in the Project Reach

The Puyallup and Carbon Rivers are much smaller than the original meltwater channel. A series of mudflows from Mount Rainier filled in this channel, creating the broad flat valley that the two rivers now meander across. These mudflows arose from volcanic activity and other events that caused alpine glaciers to catastrophically fail. Major mudflows have occurred on average every 500 to 1000 years (USGS, 2007). The Electron mudflow rushed down the Puyallup valley about 500 years ago when part of Mount Rainier's west flank collapsed. It knocked down trees as large as 2-3 meters in diameter, and encased stumps and logs in muddy rock debris about 5 meters thick.

The SR 162 bridge is within the Case II Debris Flow Inundation Level area mapped by the USGS and Pierce County (Pierce County, 2003). These Case II areas may be inundated by mudflows every 100 to 500 years. A mudflow could reach the project area in less than one hour after the local warning system is triggered.

Alluvium deposited by floods covers the older mudflow deposits. Electron mudflow deposits form a wedge of higher ground between the Puyallup and Carbon Rivers. The SR 162 bridge ties into these mudflow deposits on the right bank (Figure 10). The bridge ties into alluvial deposits on the left bank.

The alluvial soils in the project area tend to be coarse and well drained, with rapid permeability (USDA, 1979). They include the Pilchuk fine sand, Puyallup fine sandy loam, and Aquic xerofluvent soils that surround the SR 162 bridge. Mudflow soils on the right bank have poor drainage, with a compact sublayer of sandy clay that limits permeability.

Hydrology

The Puyallup River basin receives about 83 inches of mean annual precipitation above the project site (USGS Streamstats, 2007). Major floods typically arise from warm Pacific storms that follow cold late autumn storms, resulting in the "rain-on-snow" effect (James M. Montgomery, 1991). Spring snowmelt floods are usually smaller than autumn storm floods.

The USGS operates a stream gage near Orting, with a peak flow record dating back to 1932. Northwest Hydraulics Consultants recently completed a flood study to update Pierce County's Flood Insurance maps (Northwest Hydraulics Consultants, 2006). Table 1 lists peak flow statistics used in this study for the project reach. The flood of record occurred in February 1996, at 18,300 cfs. The November 2006 flood nearly matched this event, with a peak of 18,240 cfs.

Table 1. Flow Statistics for the Puyallup River at Bridge 162/006

Event	Peak Flow above the Carbon River Confluence (cfs)
10-year	12,200
50-year	16,800
100-year	18,600
500-year	22,600

Levees and Channel Alterations

Improvement districts formed in 1907 and 1914 channelized and diked most of the lower Puyallup River (James M. Montgomery, 1991). From 1939 to the early 1970s levees were constructed using material excavated from adjacent channels. A levee now lines the right bank from the Orville Bridge (RM 25.8 to the upstream side of the Burlington Northern railroad bridge (Figure 11). This levee is about 3-4 feet above adjacent pastures in the bend upstream of the bridge, but gradually fades into higher ground as it ties into the Burlington Northern railroad bridge approaches. Dense blackberry thickets obscure the levee alignment near the bridge. The Burlington Northern railroad bed is several feet higher than the top of the levee.

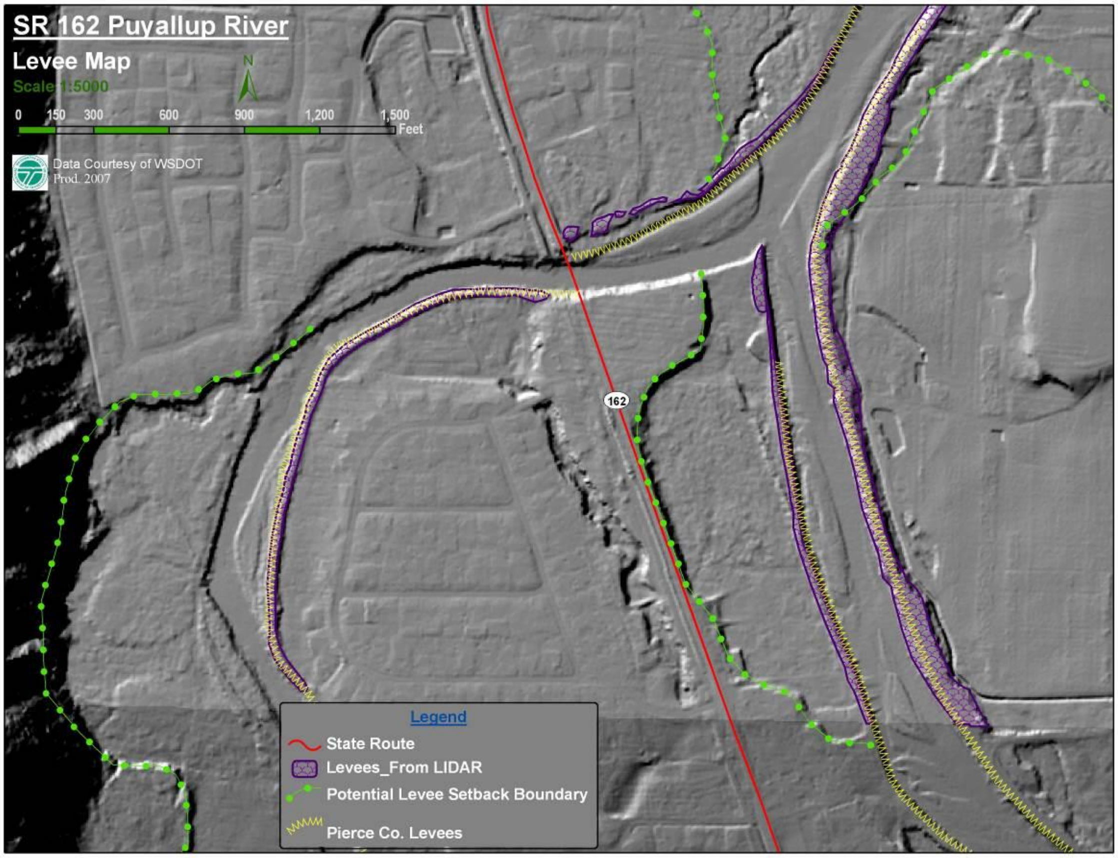

Figure 11. Levees in the Project Area

The Puyallup River flood study identified a left bank levee that begins on the downstream side of Bridge 162/006 and extends past the Carbon River confluence (Northwest Hydraulic Consultants, 2006). This levee is un-maintained and covered by mature riparian trees. The crest is uneven, and rarely lies more than two feet above the floodplain near the bridge. The crest of the levee ties into high ground next to the SR 162 embankment, and lies several feet below the top of the roadbed. The flood study did not identify levees upstream of the bridge on the left bank, but Geoengineers (2007) maps a levee that follows the left bank around the upstream bend and ties into the Burlington Northern railroad embankment near the bridge. This levee was not apparent during our field surveys, and may be obscured by vegetation.

These levees provide some protection to adjacent lands, but flooding still occurs when they fail or are overtopped. The channel has also lost capacity over time, due to aggradation associated with high sediment bedload and channel confinement. Recent studies have found that none of these levees meet FEMA standards for flood protection (Northwest Hydraulic Consultants, 2006).

Since 1996 Pierce County has been planning and implementing levee setback projects that are designed to improve river functions and reduce flood hazards. These projects focus on areas where levees can be moved back from the river, providing more flood storage and floodplain habitat. The new levees are then reconstructed to meet FEMA standards. The most recent project was completed near Soldier's Home, just upstream of the Calistoga Road bridge in Orting.

The county is in the process of identifying future levee setback projects, and is planning to identify up to three potential projects in the fall of 2007 (Randy Brake, personal communication, 2007). One potential site lies on the left bank starting at River Mile 18.4 and ending about 0.2 miles upstream of Bridge 162/006 (Geoengineers, 2007). This project would remove an existing levee above the upstream bend, but would not affect levees or floodplain areas in the immediate vicinity of the bridge (Figure 11). This project is not likely to change flow paths at the bridge, and may reduce flooding by providing upstream flood storage.

A second site is located on the left bank of the Carbon River just upstream of the confluence. This project would not affect the bridge approaches, but would construct a new levee that ties into the SR 162 embankment about 500 feet south of the bridge.

Flooding

Agricultural land and residences near the SR 162 bridge have flooded in the past, and sections of SR 162 between Orting and McMillan have been overtopped (James M. Montgomery, 1991). The February 1996 flood is the largest of record, and caused several major levee breaches. Levees around the Town of Orting were threatened, but aggressive flood fighting kept most of the town dry. The November 2006 flood was almost as large as the 1996 flood.

Northwest Hydraulic Consultants (2006) modeled this segment of the river to update the FEMA flood study for the area. This study includes the 1996 flood, and shows a greater extent of flooding near Bridge 162/006 than mapped by the 1987 FEMA flood insurance study. The updated study is used by Pierce County for flood hazard delineation and floodplain regulation.

The Northwest Hydraulic Consultants study assessed levees in the project area and found that none met FEMA standards for flood protection. The flood model therefore assumed that these levees failed. In some areas this conservative assumption leads to predicted flooding that is more extensive than occurred in 1996.

Figure 1 shows the updated flood hazard boundaries near the SR 162 bridge. The mudflow terrace on the right bank is entirely above the 100- and 500-year floodplain. On the left bank the 100-year floodplain extends onto low areas upstream and downstream of the bridges. The SR 162 roadbed is elevated above the 100-year floodplain but is covered by the 500-year flood. The elevated SR 162 and Burlington Northern bridge approaches create a pinch point that confines the floodplain to a 160-foot wide band that passes beneath the bridges. The 1-foot rise floodway is generally confined within the channel banks in the project reach, and coincides with the 100-year flood boundary beneath the bridge.

Northwest Hydraulic Consultants (2014) developed a more detailed model of the 100-year flood profile in the vicinity of the bridge. This study ties into the updated flood FEMA flood study for the area, but uses more detailed cross section data to analyze the impacts of the proposed bridge. This analysis showed the proposed bridge would cause no additional upstream water surface rise or decrease in the flow conveyance for the 100-year event.

Local Floodplain Regulations

Pierce County regulates development in the floodplain through its Critical Areas Ordinance, described in Pierce County Code Title 18E. Reconstruction of an existing public bridge may be exempt from this ordinance, unless it is viewed as an expansion of the facility. Bridge designers should work closely with Pierce County to identify all applicable requirements, especially those that deal with floodplain fill and bridge heights. The following is a brief summary of some potential requirements, based on regulations listed as of September 2007 on the Pierce County website (Pierce County Planning and Land Services, 2007).

All projects that place fill in flood hazard areas must provide a zero-rise analysis that demonstrates the project will not increase the base flood elevation, displace flood volume, or reduce flow conveyance. The zero-rise analysis must be performed with HECRAS or other county-approved hydraulic models, and must show that the project causes no rise in base flood elevation greater than 0.001 feet. To meet this standard, projects will generally need to minimize new fill or provide compensatory storage. Compensatory storage must replace lost storage between corresponding one-foot contour intervals that are hydraulically connected to the floodplain through their entire depth. Pierce County may waive the zero rise analysis requirement for structures that are elevated on piers or pilings and do not place new fill in the flood hazard area.

The county has additional requirements for floodways, which include the regulatory floodway, areas with deep and/or fast water, and areas within mapped channel migration zones. Bridge 162/006 is within the channel migration zone for the Puyallup River (Figure 12), and crosses the regulatory floodway. Most new structures are prohibited in floodways, but bridges may be allowed as long as they meet special requirements. The lowest structural member crossing the Puyallup River floodway must be a minimum of six feet above the base flood elevation.

Historical Channel Migration

Historical aerial photos from the 1960’s onward show little change in the configuration of the Puyallup River near the bridge (Figure 12). The river remains confined within a single channel that passes between levees and high banks as it flows beneath the bridge and meets the Carbon River. This static geometry is likely related to historical channel modifications and confinement by levees. The Historical Channel Migration zone in this segment is confined between high mudflow and alluvial terraces, and there is little risk of avulsion or other major channel changes.

Pierce County has designated Channel Migration Hazard zones along the Puyallup River, based on geomorphic analysis (Figure 12). The zone is about 455 feet wide at Bridge 162/006, extending 100 feet inland of the bridge on the left bank and 145 feet inland on the right bank.

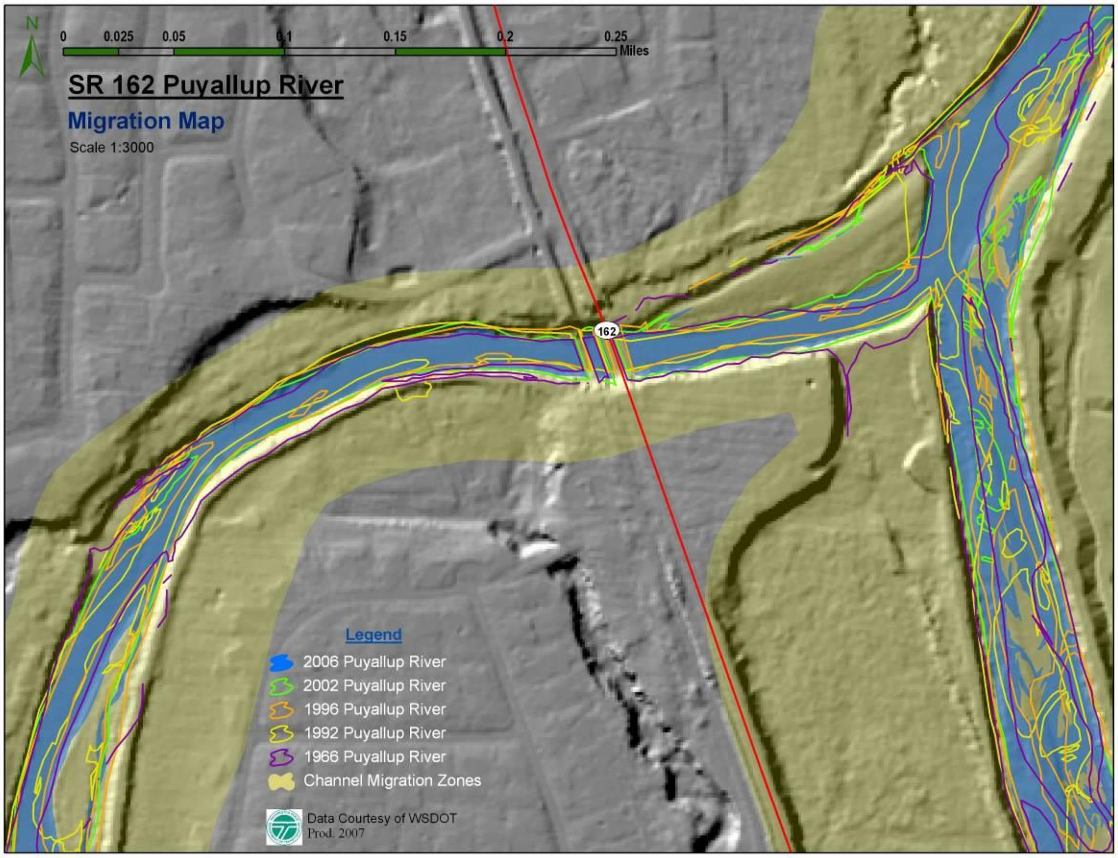

Figure 12. Channel Configurations Shown in Historical Aerial Photos

Sediment Transport and Deposition

The Puyallup River bed approaches the bridge at a gradient of about 0.1 percent, but steepens sharply to about 0.8 percent as it passes through a relatively confined segment and drops into the scour hole beneath the bridge (Figure 9). The Carbon River approaches the Puyallup at a gradient of about 0.5 percent, and delivers a large load of coarse sediment to the confluence. This creates backwater and sediment deposition between the confluence and the SR 162 bridge.

This reach of the Puyallup River has a history of aggradation and sediment bar growth. Levees disconnect the river from potential floodplain deposition zones. This causes sediment to build up within the main channel. Historically the county and private mining companies removed this material by dredging the channel and scalping gravel bars. These practices ended in the 1990's because of impacts to endangered fish species (Northwest Hydraulic Consultants, 2006).

Riparian Conditions and Large Woody Debris

Functional riparian habitat is scarce along the Puyallup River downstream of Electron (Washington State Conservation Commission, 1999). Levee construction and channelization projects removed most mature vegetation, and maintenance practices limit recovery. The remaining stands of riparian trees are fragmented and contain few mature conifers.

Large Woody Debris (LWD) is virtually absent in the Puyallup River below Electron (Washington State Conservation Commission, 1999). Most LWD in the system is derived from mature forests in the headwaters in Mt. Rainier National Park. LWD transported from the National Park flows through a steep canyon where high energy and boulders tend to break it up into smaller and less functional pieces before it reaches the project reach (Washington State Conservation Commission, 1999).

Fish Utilization and Habitat Availability

A variety of salmon species use the Puyallup River for spawning, rearing, and migration (Table 2). The Puyallup River has high natural sediment levels that can limit spawning and rearing success. However, historical data indicate the river once supported large salmon and steelhead runs (James M. Montgomery Engineers, 1991). Land development and levee construction has greatly diminished salmon habitat, and the project reach now serves primarily as a migration corridor with minimal spawning and rearing habitat (Washington State Conservation Commission, 1999). A dam and powerhouse at Electron (upstream of the project reach) limits access to 26 miles and partially dewaters 10 miles of mainstem habitat. A fish ladder constructed in 2000 restored some access to habitat upstream of the dam.

The Limiting Factors Analysis for the Puyallup basin concluded that levees and revetments preclude the development of functional riparian habitat, limiting the contribution of prey organisms and large wood to the river (Washington State Conservation Commission, 1999). Channelization and levees have also reduced river processes that form pools, side channels and other habitat features used by salmon. Channel confinement by levees increases the rate of bedload transport, leading to scour of redds and diminished spawning success.

Table 2. Salmonid Stock Status in the Upper Puyallup River Basin.

Source: WSDOT (2007b, 2007c)

Species	**Primary Utilization**	**SASI Status**
Coho (*Oncorhynchus kisutch*)	Rearing	Healthy
Winter steelhead (*O. mykiss*)	Spawning	Depressed
Fall chinook (*O. tshawytscha*)	Rearing	Unknown
Fall chum (*O. keta*)	Presence/migration	Healthy
Pink (*O. gorbuscha*)	Spawning	Depressed
Coastal cutthroat trout (*O. clarki clarki*)	Unknown	Not Rated
Bull trout/Dolly Varden (*Salvelinus confluentus*)	Presence/migration	Not Rated

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